Public perceptions and social acceptance of carbon capture and storage

Chief Scientist's Group research report

Environment Agency

Date: September 2026

Version: SC250031/R

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Published by:

Environment Agency

Horizon House, Deanery Road, Bristol BS1 5AH

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Project number: SC250031

Citation: Dow, K. (2026). Public perceptions and social acceptance of carbon capture technologies. Environment Agency, Bristol.

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Chief Scientist

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Executive summary

The UK government is actively supporting deployment of carbon capture and storage (CCS) technologies to help achieve net zero carbon emissions (Department for Energy Security and Net Zero 2025).

This report presents a quick scoping review of social scientific research on public perceptions and social acceptance of CCS and analyses four case studies of CCS projects which have achieved varying levels of public support. This evidence can offer insights into how people in the UK will respond as CCS deployment gathers pace.

Social scientific research about how different members of the public perceive CCS provides insights that can inform public engagement and support decision-makers to minimise potential risks for host communities and negative impacts on society and the environment. CCS is critical to many net zero plans, so if its implementation is hindered by public opposition, this will have serious implications for the net zero goal.

Summary of findings

- **Members of the public want CCS to be effective at storing CO_2**

Some are concerned about carbon capture being an 'end-of-pipe' solution or worry that the resources and attention going into the deployment of CCS will detract from other forms of emissions reduction. Proving that carbon can be effectively and permanently stored in the subsurface will be critical to reassuring people with these concerns.

- **Concerns about safety reflect a common desire to live in healthy and safe environments**

Members of the public will seek reassurance that CCS is safe to human health and the environment. Concerns about leakage likely reflect awareness that carbon emissions (along with other greenhouse gases) are responsible for climate change and that industrial activities that produce emissions can damage human health and the environment.

- **While CCS is increasingly presented as a means for industrial decarbonisation and climate change mitigation, this may not be the main benefit that members of the public perceive**

Additional potential benefits including the creation of 'green' jobs, the reuse of carbon, which many perceive as waste, hosting innovative technologies and ensuring a smoother or fairer transition away from fossil fuels may feel like more tangible benefits, especially for communities close to facilities. However, if these benefits do not materialise, this could lead to disappointment and opposition.

- **Choosing acceptable storage locations will be critical for reassuring members of the public that carbon is being permanently removed from the atmosphere**

Many people perceive carbon as a waste product, so the idea of storing it or reusing it through carbon capture, utilisation and storage (CCU) appeals. The flipside of this perception is resistance to the idea of storing carbon captured in another country, which raises questions in people's minds about who has responsibility for dealing with emissions.

- **While awareness of CCS is fairly low, increasing deployment is coinciding with a greater sense of urgency about mitigating climate change**

Urgency about climate change mitigation may lead some to be more accepting of carbon capture while a minority remain concerned about relying on 'end-of-pipe' solutions. Ubiquitous access to social media affects what kinds of information is available to the public and the narratives that people come to use to understand CCS projects.

- **Public engagement needs to be a two-way, ongoing process in which members of the public have opportunities to input to decision-making**

While many would like more information to inform their perceptions of these technologies, developers (many of which are energy companies) also need to offer opportunities for members of the public, especially those living near to installations, to have any concerns heard and taken seriously.

- **Public opinions are not homogenous, and the local context can play an important role in shaping acceptance**

Research with local communities can help build a picture of the context, including existing concerns about environmental protection, public health, local governance and so on, which can then inform effective public engagement and transparent decision-making.

Public acceptance of CCS cannot be taken for granted and it will always be crucial to include members of the public in decision-making about implementation and governance of this technology. Lessons about how to secure public trust and social acceptance from the case studies include:

- Carbon capture needs to be effective, and geological storage needs to be permanent.
- Operations need to be safe and monitoring data shared transparently.
- Information should be tailored to different audiences, both in terms of content and format.
- Pilots and demonstrators are crucial for building public trust.
- The association between carbon capture and the oil and gas industry can have negative and positive effects on public acceptance.
- Governance and local stakeholder relationships are critical to securing social acceptance.
- The perception of CO_2 as a waste is a barrier to social acceptance of cross-border storage.

1. Introduction

CCS first developed in North America in the 1960s in relation to enhanced oil recovery. Proposals to use it to reduce emissions associated with energy production and high-carbon industry developed from the 1970s and have gradually become integral to many countries' net zero plans. Some studies have found that members of the public prefer carbon capture when applied to industrial decarbonisation (Gonzalez, Mabon et al. 2021) and appreciate the idea of reusing 'waste' carbon through CCU (Broecks, van Egmond et al. 2016, Whitmarsh, Xenias et al. 2019). This is important emerging evidence, as much early social scientific research on CCS was conducted when it was applied to coal and gas plants (Buck 2021).

The UK government is actively supporting CCS deployment (Department for Energy Security and Net Zero 2025), including over £20 billion in funding to support the UK's first carbon capture sites in Teesside and Merseyside in 2024 (Department for Energy Security and Net Zero 2024). The Environment Agency plays an important regulatory role in CCS, particularly through the permitting of carbon capture activities, through industrial and power decarbonisation and achieving sustainable growth, through planning activities for CO_2 pipelines and as the Registry Administrator of the UK Emissions Trading Scheme. While the Environment Agency's interest is therefore largely in the capture of carbon, this report covers social scientific evidence on all aspects of CCS and CCU, since members of the public do not tend to distinguish between the different elements in the way that regulators do.

This report summarises social scientific research on public perceptions and social acceptance of CCS and CCU, focusing on literature that discusses the perceptions of the UK public. It also analyses four case studies which illustrate different levels of public acceptance and how these can vary depending on public engagement, effectiveness of the installation, impacts on the local environment and community, transparency of information and where and how carbon is being stored. As the first UK-based carbon capture projects are only just being deployed, the case studies are from Norway, Iceland, Australia and Japan.

Evidence about how publics perceive CCS provides insights that can help regulators and policymakers anticipate public acceptance and opposition as well as understanding the reasons for those responses. This can then inform public engagement and support decision-makers to minimise potential risks for host communities and negative impacts on society.

The 2025 Department for Energy Security and Net Zero public attitudes tracker found that awareness and knowledge of CCS was similar to previous years, with 68% of people in the UK aware of it and 20% claiming some knowledge. It also found that 44% supported CCS, while opposition was 12%, up from 10% in the previous year (Department for Energy Security and Net Zero 2025). In general, research shows that public perceptions of CCS are mixed and somewhat ambivalent (Broecks, Jack et al. 2021, Görsch, Perlaviciute et al. 2025). There is evidence that acceptance of CCS is higher in the UK than some

comparable countries (Whitmarsh, Xenias et al. 2019) and that residents in some of the areas where it is likely to be deployed are supportive. However, this acceptance is relatively weak and has not yet been tested by the experience of living with installations, so it should not be assumed that it will remain stable. There is also a minority of people with strong objections to CCS in the UK because of concerns that it will divert resources and policy attention away from other forms of climate mitigation (Wickett-Whyte, Boelman et al. 2021).

Public opposition is frequently cited by stakeholders as a barrier to the scaling up of CCS. Opposition has played a major part in stopping some projects from progressing; the best-known example of this is the Barendrecht project in the Netherlands (Oltra, Upham et al. 2012, Bickerstaff, Abram et al. 2024). However, there are also technical, financial and governance challenges and, like any technology, whether CCS is accepted and successful will depend on the context in which it is being deployed. When projects are cancelled, as has frequently been the case with CCS, this can add to perceptions that the technology is not feasible as well as hindering innovation (Wang, Akimoto et al. 2021). If the implementation of CCS is constrained by public opinion or other factors, this will present a challenge for achieving net zero, with implications for climate change mitigation and financial and technical impacts for energy systems (van der Zwaan, Broecks et al. 2022).

Methods

Literature was searched in the Scopus database in July 2025. The search terms were: ‘carbon capture storage public perceptions’, ‘carbon capture storage public engagement’ and ‘carbon capture utilisation public perceptions’, with results limited by discipline to Social Sciences. The search results were screened for relevance to the research topic, publication date (within 10 years) and whether the full text was available. Additional sources were identified through the references cited in relevant publications and through literature already known to the author. In total, 52 articles were reviewed.

To complement the literature review, the report examines four case studies of CCS projects which have achieved varying levels of public support. The case studies comprise:

- Sleipner, the world’s first commercial CCS project, in Norway
- Tomakomai, Japan’s first full-chain CCS demonstrator plant
- Carbfix, which demonstrated the mineralisation of CO_2 for storage, based in Iceland
- Gorgon, the largest CCS plant in the world, based in Australia.

Case studies were chosen based on availability of information from academic literature and publicly available sources identified through internet searches. They were selected to capture a range of public reactions, while also attempting to cover examples that may be less familiar to readers who have followed the debates around carbon capture and storage (see, for example: Oltra, Upham et al. 2012, von Rothkirch and Ejderyan 2021, Wang, Akimoto et al. 2021, Bickerstaff, Abram et al. 2024).

The following three chapters outline the findings of the quick scoping review of research in the field. Chapter 2 examines research into public perceptions of CCS in detail, focusing

on research conducted in the UK and looking at the different associations that people have with CCS including its risks and benefits. Chapter 3 discusses research on public awareness of CCS and some of the narratives in public discussions about the technology. Chapter 4 explores stakeholders' actions and the themes of trust and justice in relation to public engagement. Chapter 5 reviews the evidence for social acceptance of CCS, looking at both individual demographic factors and community characteristics which can influence acceptance. Chapter 6 presents the case studies, outlining pertinent information about the cases and how they have been received by the public, and identifying what can be learnt from them. Chapter 7 offers a conclusion.

2. Public Perceptions of CCS

This chapter reviews literature on public perceptions of CCS, focusing particularly on research with UK participants. The sections reflect the most prominent themes that emerged from the quick scoping review.

2.1 Perceptions of CCS as an Effective Form of Climate Change Mitigation

Summary: Members of the public want CCS to be effective at contributing to climate change mitigation. Some see CCS as an 'end-of-pipe' solution and therefore less acceptable than other techniques which avoid carbon emissions rather than storing them. Some people worry that the resources and attention going into the deployment of CCS will detract from other forms of emissions reduction like renewable energy. People with these concerns are likely to be reassured if CCS is approached as an intermediate technology that will help us address the urgent problem of climate change alongside technologies and behavioural changes that avoid and reduce emissions.

Climate change mitigation is at the heart of public perceptions about CCS. In one sense, this is about its effectiveness at achieving its objective. But it also relates to broader ethical and political questions about how societies and governments are responding to climate change.

Various studies have found that people tend to prefer solutions that address emissions at the source and express concerns about CCS being an 'end-of-pipe' solution (Mabon, Shackley et al. 2014, Wickett-Whyte, Boelman et al. 2021, Witte 2021) or that it will out-compete renewable energy in terms of resources (Mabon and Shackley 2015, Broecks, Jack et al. 2021). This concern is summarised in a systematic review article: 'some people think CCS can be a bridge technology that "buys time" and allows countries to develop better methods for climate mitigation, while some people simultaneously indicate that CCS might delay the implementation of renewables by increasing fossil fuel reliance' (see also Larkin, Gattinger et al. 2023, Görsch, Perlaviciute et al. 2025).

Researchers have found that, for some people, CCS and CCU are fundamentally immoral, unnatural or 'playing god' (Thomas, Pidgeon et al. 2018, Engelmann, Haverkämper et al. 2025). For example, in a public dialogue[1] that took place in several cities across the UK commissioned by the Department for Business, Energy and Industrial Strategy:

[1] Public dialogues are used to get in-depth insights into how members of the public perceive issues in science and technology and often consist of structured and intensive workshops and discussions led by facilitators.

> A small group of participants, across locations, were strongly opposed to CCUS having any role in the pathway to net zero and their opposition hardened over the dialogue. They felt that CCUS would tackle the symptoms rather [than] the causes of global warming by not reducing emissions, calling it a “sticking plaster.” They viewed CCUS as unsafe and described it as “unnatural,” reflecting their strong feelings that CCUS is undesirable. (Wickett-Whyte, Boelman et al. 2021)

While this is a minority view, it shows that some people have strongly negative feelings about carbon capture, which may not change with information provision.

In the same study, many participants felt that if CCU was going to be implemented, this should be as soon as possible, because of the urgency of mitigating climate change and because they assumed that implementation would take time. Participants wanted to know that CCU would be installed in time to be effective while not being rushed and therefore potentially unsafe (Wickett-Whyte, Boelman et al. 2021).

Among different applications of CCS, members of the public are most positive towards industrial decarbonisation (Broecks, Jack et al. 2021, Gonzalez, Mabon et al. 2021). This is an important finding given that much of the early research on public perceptions of CCS was conducted when it was more likely to be applied to fossil fuel plants, so it may have diminished relevance (Buck 2021, Määttä and de Gooyert 2025). If CCS becomes increasingly applied to industrial decarbonisation rather than coal and gas installations, public acceptance may increase.

As well as technical effectiveness, publics are concerned about policy and governance strategies and whether CCS will be part of a broader transition (L′Orange Seigo, Dohle et al. 2014). Some researchers have therefore recommended that policymakers frame CCS as ‘an intermediate technology for specific applications with well-specified timeframes for phase-out’ (Gonzalez, Mabon et al. 2021) or as a ‘regulated breathing space’, which establishes the need for policy and regulatory support but also an exit strategy for these technologies (van der Zwaan, Broecks et al. 2022).

The evidence summarised here suggests that, given the importance of CCS for reaching net zero, it will be essential to take account of public concerns about what part CCS will play in the transition, including questions about how CCS will complement other forms of emissions reduction and sequestration and how long we will rely upon it.

2.2 Safety, Risk and Hazard Perceptions Associated with CCS

Summary: Concerns about safety reflect a common desire to live in healthy and safe environments. Members of the public will seek reassurance that CCS is safe to human health and the environment. If an incident occurred at a CCS installation, storage facility or related infrastructure (e.g. transport or pipelines) this would be likely to negatively affect public perceptions, possibly in the long-term. Concerns about leakage likely reflect awareness that carbon emissions (along with other greenhouse gases) are responsible for climate change and that industrial activities that produce emissions can damage human health and the environment.

As with any technology, members of the public are concerned about whether CCS represents risks to health, hazards to people and wildlife or other negative unintended consequences (Wickett-Whyte, Boelman et al. 2021, Witte 2021). As Görsch and colleagues articulate it, ‘many concerns people have about local projects do not reflect selfish motivations, but rather a concern for the wellbeing of others, nature, and the environment, such as concerns about impacts on wildlife and plants, economic feasibility, and community impacts' (Görsch, Perlaviciute et al. 2025).

Some of the health risks that people associate with CCS reflect generic risks such as industrial accidents and hazards entailed with large-scale construction. But there are also specific fears about the effects of CO_2 as a pollutant, both in relation to contributing to climate change and to perceived effects of leakage on human and animal health (Thomas, Pidgeon et al. 2018, von Rothkirch and Ejderyan 2021). In a study in Germany, Arning and colleagues (2020) found that people’s perceptions of benefits and risks were strongly shaped by their perceptions of whether the risks of CCU were controllable.

In the public dialogue research that took place in several UK cities and was commissioned by the Department for Business, Energy and Industrial Strategy cited in the previous section, several participants believed that reducing carbon emissions would mean the air would be cleaner around sites, despite having been corrected by the facilitators (Wickett-Whyte, Boelman et al. 2021). Given ongoing research into the potential risks of amines used in carbon capture to the environment and human health, this perception may need to be managed carefully, to ensure that people living close to CCS sites have access to information about the impacts on air quality of these technologies and how these will be monitored and managed going forward.

Public fears about hazards of CCS tend to focus on the storage element (Görsch, Perlaviciute et al. 2025). Deliberative research[2] in the UK found that, 'CCS evoked a range of feelings and was viewed by some as transgressing important barriers between natural and human worlds. Risks to human and animal life from leakage or induced seismicity tended to be interpreted as posing lasting, potentially irreversible damage to complex living systems' (Thomas, Pidgeon et al. 2018, von Rothkirch and Ejderyan 2021). These researchers found that use of the ocean subsurface provokes concerns, which Wickett-Whyte and colleagues also found in their more recent study:

> The storage of CO_2 under the seabed was the most disquieting safety concern for participants, but they also had worries about the safety of CO_2 being transported. Participants highlighted the risk of leaks and earthquakes, and the harm these might cause to marine life. Participants wanted the entire CCUS process (including

[2] Deliberative research is a qualitative method that captures participants’ views on an issue after they have had a chance to deliberate on it following exposure to information and different perspectives.

> decommissioning) to be safe, and for safety features to be explicitly and accessibly communicated, supported by a strong evidence base. (Wickett-Whyte, Boelman et al. 2021)

Research participants feared that if carbon leaked or there was a major accident, this would undo the carbon emissions reduction and pose a threat to future generations (Wickett-Whyte, Boelman et al. 2021). If there were a safety incident involving a CCS facility this would also be likely to negatively affect public acceptance of the technology (L′Orange Seigo, Dohle et al. 2014).

Other risks that people associated with CCS included visual impacts, odour and noise, especially in relation to construction, laying of pipelines and transportation of carbon (von Rothkirch and Ejderyan 2021, Wickett-Whyte, Boelman et al. 2021). This was often linked with concerns about effects on housing and tourism. A review of cases around the world found concerns about falling house prices (von Rothkirch and Ejderyan 2021), while Wickett-Whyte and colleagues (2021) found that participants in Aberdeen and Port Talbot were worried that the influx of workers associated with CCS deployment would increase the prices of houses and other goods. As this indicates, public concerns reflect specific socio-economic conditions.

2.3 Perceived Benefits of CCS

> Summary: While CCS is increasingly presented as a means for industrial decarbonisation and climate change mitigation, this may not be the main benefit that members of the public perceive. Other projected benefits including the creation of ‘green’ jobs, the storage or reuse of a ‘waste’ product, hosting innovative technologies and ensuring a smoother or fairer transition away from fossil fuels may feel like more tangible benefits, especially for communities close to facilities. However, if these benefits do not materialise, this could lead to disappointment and opposition.

If people perceive benefits from CCS, they are more likely to accept it (Oltra, Upham et al. 2012, L′Orange Seigo, Dohle et al. 2014). Understanding what benefits people perceive in relation to CCS can therefore provide important insights into acceptance and inform public engagement on this technology.

Broecks and colleagues (2016) found that arguments that CCS will contribute to climate change mitigation were less persuasive than other arguments such as that CCS is a way of dealing with CO_2 as a ‘waste product’ or that CCS development will stimulate economic growth. For many people, local benefits like job creation may be more tangible than contributing to global emissions reduction.

A systematic review (Görsch, Perlaviciute et al. 2025) found that economic benefits associated with CCS across several studies included prolonging the use of relatively cheap fossil fuel energy (see also L′Orange Seigo, Dohle et al. 2014, von Rothkirch and Ejderyan 2021) and supporting economic growth and secure jobs, although there were also public concerns that CCS would be an expensive technology.

Operators and policymakers expect CCS to provide jobs, but qualitative research has found that these promises are not always taken at face value. Members of the public, trade unions and NGOs in the UK have raised questions about the types of job available, whether they would be accessible to local people, the sustainability of jobs and whether economic benefits will accrue to local communities (Gonzalez, Mabon et al. 2021, Wickett-Whyte, Boelman et al. 2021).

Hosting carbon capture facilities could be a source of local pride for some communities, because of a sense that they are at the forefront of innovation (von Rothkirch and Ejderyan 2021) or that this is a way of supporting existing industries to transition to more sustainable practices (Thomas, Pidgeon et al. 2018, Witte 2021). Place-based considerations and community characteristics in relation to social acceptance of CCS are discussed in more detail in chapter 5.

2.4 Perceptions of Usage and Storage in CCS

> Summary: Choosing acceptable storage locations will be critical for reassuring members of the public that carbon is being permanently removed from the atmosphere. Many people perceive carbon as a waste product and so the idea of reusing it through CCU appeals. However, the flipside of this perception is a resistance to the idea of storing CO_2 captured in another country, which raises questions about who has responsibility for dealing with carbon.

Research on public perceptions tends to focus on CCS in general, but there are some indications about how people think about the different aspects of carbon capture. For example, a preference for CCU over CCS has been found among some UK research participants (Mabon and Shackley 2015, Broecks, van Egmond et al. 2016, Whitmarsh, Xenias et al. 2019), in Germany (Linzenich, Arning et al. 2019) and in international research (Görsch, Perlaviciute et al. 2025).

As the section on risk perceptions above showed, the storage element is an important factor in public perceptions of CCS. While some developers and policymakers have assumed that members of the public will prefer offshore storage because of concerns about the safety of the immediate community around an onshore storage site (Mabon, Shackley et al. 2014), this is not always borne out. Many communities (including those not living in coastal areas) are also concerned about marine ecosystems, so there is no clear trend in acceptance of onshore versus offshore storage (Mabon, Shackley et al. 2014, Gough, Cunningham et al. 2018, von Rothkirch and Ejderyan 2021, Merk, Nordø et al. 2022).

One study (Merk, Nordø et al. 2022) compared attitudes of German and Norwegian respondents to cross-border storage. They found that storing carbon in another country does not necessarily lead to more positive perceptions of CCS (see also Liu, Xu et al. 2022). Norwegian respondents had high acceptance of CCS, including when carbon sourced in Norway is stored in Norwegian territory (81% or respondents evaluated this positively), but their support reduced by half when asked about a project to store carbon

captured in Germany in Norwegian territory. By contrast, around half of German respondents evaluated CCS positively and this was not affected by the storage location. Attitudes to storing imported carbon are discussed further in

6.3 Case Study 3: Carbfix, Iceland.

2.5 Comparisons with Other Technologies

Summary: People draw on their knowledge of familiar technologies when assessing novel ones, which can have ‘ripple effects’ on their perceptions and contribute to certain associations building up around technologies. When compared with other net zero technologies, CCS tends to receive moderate support and be less popular than renewable energy.

Some researchers have examined how people compare CCS with other technologies, including those which might be alternatives and those that could work alongside CCS. Non-specialists generally draw upon their knowledge and familiarity with other technologies when assessing unfamiliar ones (Gough, Cunningham et al. 2018). The technologies that they find comparable can expose unexpected but revealing dimensions to public perceptions. In the public dialogue commissioned by BEIS, for example, 'Participants drew comparisons with oil rigs (which they generally considered safe, but said that oil spills do happen), fracking (some participants said this could cause earthquakes) and nuclear waste (which some participants said risks contamination in the longer term)' (Wickett-Whyte, Boelman et al. 2021). Other research has also found that publics draw comparisons between CCS and shale gas (Oltra, Upham et al. 2012, Gough, Cunningham et al. 2018, Swennenhuis, Mabon et al. 2020).

One review article (Görsch, Perlaviciute et al. 2025) compared acceptability for a range of eleven energy sources and mitigation technologies, finding that CCS acceptability was ‘moderate’, so less acceptable than renewable technologies (solar, hydroelectric and wind) and more acceptable than oil and coal. Other technologies in the moderate category were biomass, natural gas and nuclear energy. This echoes numerous studies that show strong public support for renewables (Difford 2024, James 2024, DESNZ 2025), as well as the public dialogue commissioned by BEIS, which found that, ‘where participants made direct comparisons between renewable energy and CCUS, they tended to describe renewable energy generation as greener and cleaner, or as a simpler, cheaper or more reliable manner of achieving CO_2 reductions' (Wickett-Whyte, Boelman et al. 2021). Some researchers have found that CCS is more supported when it is paired with bioenergy (Whitmarsh, Xenias et al. 2019). The relationship between public perceptions of CCS and other technologies, including BECCS and DACCS, would be an interesting area for future research, as it is likely to add another layer to the public concerns explored earlier about whether CCS represents a necessary part of climate change mitigation.

3. Knowledge and Awareness of CCS

Summary: While awareness of CCS is fairly low, increasing deployment is coinciding with a greater sense of urgency about mitigating climate change – this may lead some to be more accepting of carbon capture while a minority remain concerned about relying on ‘end-of-pipe’ solutions. Ubiquitous access to social media affects what kinds of information is available to the public and the narratives that people come to use to understand CCS and specific projects. While enthusiastic framings of technologies can increase acceptance, members of the public may be sceptical if they feel they are being told a one-sided story.

Awareness of CCS is low amongst most publics, including in the UK (Buck 2021, Wickett-Whyte, Boelman et al. 2021, Larkin, Gattinger et al. 2023, Wædegaard, Hvemon et al. 2024). Given this low awareness, research about public perceptions often includes a step which provides participants with information about the technologies and their applications. Learning more about the technologies (and alternatives) can lead to new concerns but also greater acceptance (Thomas, Pidgeon et al. 2018, Wickett-Whyte, Boelman et al. 2021). Unfamiliar risks are often of greater concern to the public than familiar ones, which is one reason why CCS sites may be more likely to be accepted in places that have hosted similar installations and why tours of proposed sites and visual displays and infographics can help foster acceptance (Lofstedt 2015), as case studies 1 and 3 demonstrate.

An older review of literature found that knowledge about CCS had a ‘moderate at best’ effect on acceptance and observed that the context in which a project is being deployed is more influential (L′Orange Seigo, Dohle et al. 2014, see also Broecks, Jack et al. 2021). However, a more recent study found that, 'A positive relation was observed between the level of awareness and the perception of necessity; that is to say, the more participants feel they know about CCS, the more they view it as a necessary strategy in the energy transition' (Gonzalez, Mabon et al. 2021). While this could reflect a growing enthusiasm for CCS, it may also reflect an increased sense of urgency about mitigating carbon emissions by all available means.

People do not form judgements about technologies based only on scientific or technical information. When technologies are unfamiliar, people can see the inevitable uncertainties surrounding them as a cause for concern and will draw on lived experience, the views of peers and other trusted messengers and their own judgements about the credibility of different sources of information to draw conclusions about its acceptability (Mabon and Shackley 2015).

As Waedegaard and colleagues (2024) point out, the low public awareness of CCS means that perceptions are likely to be malleable and open to influence, or to familiarity with a specific example. As media coverage of CCS increases, certain narratives will come to dominate, themselves shaped by what seems to resonate with the audience and which actors are involved in the debate.

A study of coverage of CCS in British newspapers in 2011 observed that both positive and negative reports framed CCS as a contest between opposing forces or actors, which can be won or lost and in which government may be seen as a hero or a villain (Nerlich and Jaspal 2013). People now have access to a much broader range of information, including social media platforms that can instantly publicise support and objections, information and misinformation about technologies and projects. This is likely to play an important role in how people come to form opinions about CCS (Buck 2021), as case studies 1 and 3 illustrate. Increased coverage of CCS across social media may spread information of varying quality and credibility which may influence public attitudes and amplify risk perceptions.

In experimental research in Denmark, which has recently become more supportive of CCS at the policy level and in newspaper coverage, Waedegaard and colleagues (2024) found that an 'enthusiastic' framing of CCS was associated with more positive attitudes towards the technology and that a 'critical' frame has a negative effect on public attitudes. They also found that these effects were significantly influenced by environmental attitudes (those with highest environmental concern were most influenced by the enthusiastic framing) and prior awareness of CCS. As this shows, a frame that persuades one individual will not necessarily convince another, since frames interact with individuals' existing values, experiences and knowledge.

Other research has found that framing CCS as a mitigation technique can be unconvincing to some. One study measured Dutch citizens' responses to arguments used by proponents of and opponents to CCS (Broecks, van Egmond et al. 2016). It discovered that respondents found arguments about CCS contributing to protecting the climate (such as 'the climate problem cannot be solved without CO2 storage') less convincing than other arguments. The most persuasive argument for these respondents was industrial decarbonisation, i.e. 'CO_2 storage can be used in industries where there are no other options for reducing CO_2 emissions'. So, while the main argument for CCS amongst stakeholders is its role in climate change mitigation, if this is not always persuasive for members of the public, proponents will need to convey other potential benefits of the technology when advocating for its implementation.

4. Stakeholders' Actions: Trust, Public Engagement and Justice

Summary: Trust in stakeholders and regulators is critical for acceptance of CCS, but it will vary depending on the context and existing relationships. While some may disagree about how CCS should be regulated, there is general agreement that it needs to be regulated to be safe for humans and wildlife and effective at permanently storing carbon. Public engagement needs to be a two-way, ongoing process in which members of the public have opportunities to input to decision-making.

As well as the technology itself, public acceptance is shaped by perceptions of the operators, developers, regulators and other stakeholders associated with it. This is summarised by Wickett-Whyte and colleagues from their public dialogue with people across the UK:

> Because of concerns about safety and costs, participants felt strongly that contracts for CCUS projects should be awarded openly and transparently, preferably to what participants described as "ethical" companies with a proven record of delivery on similar projects. Some stated a preference for UK companies to deliver CCUS projects. Participants thought there should be oversight and regulation of all stages of CCUS projects which is independent of both government and industry. In particular, this oversight should ensure that CCUS projects are safe and that wildlife is protected. (Wickett-Whyte, Boelman et al. 2021)

Despite their being a general sense from the literature that public trust and confidence is an important element in the implementation of CCS (Larkin, Gattinger et al. 2023, Otto, Chilvers et al. 2023), relatively little of the research reviewed here explored people's perceptions of stakeholders or broader questions of trust. There is some evidence that members of the public are reluctant to trust industry with developing CCS (Gonzalez, Mabon et al. 2021) and that projects which are led by scientists and seen as independent from both government and industry are more trusted (Oltra, Upham et al. 2012, Gough, Cunningham et al. 2018). However, there is also public support for the idea that government should provide subsidies to the development of CCS (Gonzalez, Mabon et al. 2021) and where there is public trust in industry, people tend to be more supportive of industrial CCS implementation (Broecks, Jack et al. 2021).

Xenias and Whitmarsh conclude that, 'trust in information sources and decision-makers is one of the most critical factors in effective engagement with CCS' (Xenias and Whitmarsh 2018, see also Wickett-Whyte, Boelman et al. 2021). People also need to trust developers and regulators to safely manage projects (Wickett-Whyte, Boelman et al. 2021). Trust can be influenced by past experience with other technologies and with the same or similar organisations, which can affect perceptions of their competence and motivations (Gough, Cunningham et al. 2018).

Trust is, of course, a two-sided coin, and developers, operators and regulators also need to trust members of the public. This is particularly apparent in relation to public engagement, which is often when members of the public and developers of projects and technologies come into contact. Xenias and Whitmarsh (2018) observe that public engagement is commonly undertaken with the instrumental aim of bringing members of the public on board with a technology or project and that technology roadmaps often perceive members of the public as barriers to the roll-out of technologies (see also Stephanides, Chilvers et al. 2025). They write:

> Underlying [such] instrumental rationales is a 'deficit model' of the public as lacking in requisite technical information to make 'correct' decisions; and (usually) an assumption that 'the public' is homogenous. In contrast to this, research shows that public views and contexts are highly varied and that knowledge about technical issues is a poor predictor of attitudes, risk perceptions or behaviour. (Xenias and Whitmarsh 2018)

Relatedly, Otto and colleagues (2023) point out that, while researchers often think of trust as an outcome of public engagement, trust also enables, and may even be a prerequisite for, participation in public engagement. Others have noted that, typically, public engagement processes can feel to participants as if they are being consulted at a point when decisions have already been made, including the most fundamental questions of how climate change should be mitigated (Mabon and Shackley 2015).

The topic of procedural justice features in much social science literature on low carbon technologies but is relatively absent from the literature on CCS reviewed here. Procedural justice describes whether decision-making processes have been followed transparently and fairly. In relation to research with stakeholders involved in the implementation of CCU in Canada, Larkin and colleagues observe:

> Interestingly, this topic [procedural justice] did not garner a lot of attention from study participants, but those who mentioned it pointed to risks at both the policy and project levels. According to one interviewee, '[It is important to] always start with the regulations and policy. Society feels comfortable and protected through regulations and policy. Listen to their concerns and factor that into how we develop and deploy the technology as well so […] you're bringing […] society into the technology, their involvement and the raising of concerns. [There needs to be a] desire and willingness to listen to stakeholders about their concerns.' (Larkin, Gattinger et al. 2023)

In similar research with CCS stakeholders in Scotland, the Netherlands and Norway, Swennenhuis and colleagues found that interviewees in Scotland expected government to regulate CCS 'in a way that harnesses the skills of private sector developers yet also allows benefits to accrue primarily to society at large' (Swennenhuis, Mabon et al. 2020). Their research was focused on whether the implementation of CCS can be part of a 'just transition', or in other words, whether regions that are economically reliant on carbon-intensive industries can transition to low-carbon industry in a way that treats those affected fairly. They report that there was a common understanding amongst interviewees that:

> for CCS to contribute to a just transition it has to (a) make a contribution to climate change imperatives; (b) help to mitigate the economic and employment effects arising from declining or maturing industries; and (c) be undertaken in a manner that helps to redress (or at least does not increase) uneven vulnerabilities and inequalities in society. (Swennenhuis, Mabon et al. 2020)

4.1 Public Engagement

> Summary: Public engagement is likely to work best when actors have carefully considered the messages they want to convey, how they will convey them, who is involved in the process and when to engage the public. But it is also important to be clear and transparent about why the public are being engaged. Trust provides a more stable foundation on which to build relationships with the public and this can be undermined if they perceive they are being told what to think or being persuaded rather than listened to.

Engaging with the public, at national and local levels, is important for communicating information about technologies, their risks and benefits and the decision-making processes behind their implementation (Broecks, Jack et al. 2021). Done well, it can help build trust between the public and other stakeholders, but it needs to be carefully designed and implemented.

The following recommendations for public engagement draw on a report for the CCUS Poland Association by the Clean Air Task Force and a briefing for the EU CCUS Projects Network (Parmiter and Bell 2020, Gładysz and Kupiec 2025):

- Engage communities early and be proactive – and continue to engage throughout the project
- Map stakeholders and research the local context, including existing controversies and key decision-making processes
- Share data transparently and be open about risks and opportunities, especially for the local community
- Location and timing of meetings with the public and stakeholders should reflect their needs
- Integrate social acceptance into permitting, for example through a social impact assessment, and allow for grievances to be reported
- Provide information to the public, but make it a two-way conversation
- Be respectful of different opinions and experiences
- Identify key stakeholders, gatekeepers and advocates

Many researchers recommend that public engagement should happen as early as possible (L′Orange Seigo, Dohle et al. 2014, Lofstedt 2015). Xenias and Whitmarsh (2018) note that 'Engaging the public early can avoid attitudes becoming polarized, and can ensure public concerns and values are fed into decision-making in a genuine way – rather than after options have been closed down'. As they point out, this not only ensures that members of the public feel they have been given a meaningful opportunity to input into

decision-making but can also lead to better relationships with stakeholders and more sustainable and stable outcomes for the process.

Public opinions can shift over time and as new information is absorbed, so using arguments that the audience are likely to perceive as important, persuasive and not completely novel is recommended (Broecks, van Egmond et al. 2016). As this indicates, understanding public perceptions of the technology in question can help inform and support public engagement (Broecks, Jack et al. 2021). Making public engagement messages relevant to the local context is important. Learning about other places where the technology in question is already operational, especially if it is somewhere that is viewed positively or as a similar kind of place, can also provide reassurance to those who are less familiar with CCS (Wickett-Whyte, Boelman et al. 2021).

Research with experts in CCS found that they were concerned about inadvertently creating the wrong impression about the technology because of the challenges of communicating technical information to the general public, especially given low familiarity with the technology (Xenias and Whitmarsh 2018). Several researchers have emphasised the importance of transparency and honesty in engaging with the public (L'Orange Seigo, Dohle et al. 2014, Arning, Offermann-van Heek et al. 2020, Wickett-Whyte, Boelman et al. 2021). As well as written documents and oral presentations, visual information including site visits and demonstrations can help people understand unfamiliar technologies (Lofstedt 2015, Wickett-Whyte, Boelman et al. 2021). Members of the public may not be used to long verbal presentations or may find attending meetings intimidating, so including a range of different ways of engaging with the project can make engagement more inclusive.

Many studies have shown that members of the public expect a two-way process and to be listened to when they are engaged (ter Mors and van Leeuwen 2023). This is summarised by the following example in the UK:

> Participants wanted there to be inclusive and meaningful engagement with local communities directly impacted by CCUS, with people's views listened to. They thought it was important to provide clear information, which explains risks as well as benefits, to enable local communities to have informed views on projects. In particular, they felt local communities should be given transparent information on safety, costs and funding, the role of CCUS in reaching net zero, local environmental impacts (to wildlife and the land) and economic benefits. (Wickett-Whyte, Boelman et al. 2021)

Members of the public appreciate being given genuine opportunities to have their voices heard and one way of achieving this is to provide feedback and updates on how their input has been addressed as a project progresses (ter Mors and van Leeuwen 2023). Ensuring that different sectors of the community are represented in public engagement activities is important from the point of view of procedural justice and because it will allow for a more comprehensive understanding of public opinion.

Members of the public tend to be less trusting of energy companies, so even if they follow recommendations about how to do public engagement well, they may face challenges in being trusted. This may be particularly relevant for those who are sceptical about CCS because of concerns about it being a ‘end-of-pipe’ solution. Some have therefore recommended that developers work with other actors who are seen as more independent or trustworthy, such as local citizen groups, NGOs or local government representatives, though this needs to be carefully tailored to the context (L′Orange Seigo, Dohle et al. 2014, Wickett-Whyte, Boelman et al. 2021).

5. Social Acceptance of CCS

Social acceptance tends to be higher when people are asked what they think of technologies in general compared to specific local examples. Some have found that this is the case for CCS (Wickett-Whyte, Boelman et al. 2021). However, other researchers have found that proximity to a (proposed) facility is associated with greater acceptance, though this 'YIMBY' (Yes In My Back Yard) effect may be higher for capture facilities than storage sites (Whitmarsh, Xenias et al. 2019). This chapter outlines both individual factors and community characteristics that influence social acceptance of CCS.

5.1 Individual Factors

Summary: Public opinions are not homogenous, and the local context can play an important role in shaping acceptance. Concern about climate change is related to public acceptance of CCS, though in the UK, people also consider whether it will have negative impacts on the environment and wildlife.

The relationship between environmental values and acceptance of CCS is a complex but important one. Concern about climate change is associated with support for CCS in the UK and elsewhere (Whitmarsh, Xenias et al. 2019, Broecks, Jack et al. 2021, Witte 2021), including when climate change is perceived as an imminent risk (von Rothkirch and Ejderyan 2021). Similarly, climate scepticism is associated with lower support for CCS (Broecks, Jack et al. 2021, von Rothkirch and Ejderyan 2021). However, this is not a stable or universal phenomenon – one study found that greater concern about climate change led to more support for CCS among Norwegian respondents but not German ones (Merk, Nordø et al. 2022). Another study also found that British people were less accepting of CCU if they thought it might have negative effects on the environment and wildlife; this was especially true for those who identified as 'green' (Wickett-Whyte, Boelman et al. 2021). As noted, there is some evidence that those who are less concerned about climate change can be supportive of CCS if they perceive other benefits. For example, a UK study found that CCU may be more appealing to climate change sceptics because they support the idea that it reuses a waste product (Whitmarsh, Xenias et al. 2019).

As well as climate change views and environmental values, other individual factors that have been found to be relevant to acceptance of CCS include gender, age and relationships with the relevant industries. The evidence on these associations will become stronger with greater research and as people become more familiar with the technologies. Men tend to be more supportive of CCS than women (Broecks, Jack et al. 2021, Merk, Nordø et al. 2022) and younger people tend to be more supportive than older ones (Whitmarsh, Xenias et al. 2019, Broecks, Jack et al. 2021). There is also evidence that those who have experience working in the oil and gas sector are more supportive of CCS in the UK (Whitmarsh, Xenias et al. 2019) and Norway (Merk, Nordø et al. 2022).

One study found that support for CCS was associated with right-wing political views and positive attitudes to technology ('technophilia') (Whitmarsh, Xenias et al. 2019). There is little evidence about the role that religion may play in support for this technology, but one UK study from over a decade ago found that Muslims and Christians both had lower perceptions of the urgency of climate change compared to secular participants due to their belief in the afterlife and in divine intervention. Secular participants were the most supportive of CCS, followed by Christians, with the lowest support amongst Muslim participants, who considered CCS problematic due to beliefs in environmental stewardship, harmony values and the intrinsic value of nature (Hope and Jones 2014).

5.2 Community Characteristics, Locale and Social Fit

Summary: Local acceptance of CCS will reflect various factors: familiarity with the technology and similar industries, trust in the developers and regulators, the quality of public engagement and perceptions of risks and benefits for the local environment and community.

Beyond individual characteristics, there is evidence that community identity, local industrial history, locale and socio-political context are related to acceptance of CCS. As with public perceptions more generally, acceptance at the local level reflects considerations of the timing of the project, the profile of those associated with it, risk and benefit perceptions, public engagement and siting. Values such as energy security, sustainability, waste management and being pro-innovation will have different meanings and worth in different settings.

A study by Oltra and colleagues compared public responses to several different carbon capture projects. It was published in 2012 but still raises important points for today. It states:

> A project is more likely to generate a positive community reaction if it is at a research-scale; if it is led by a public research organization with well-established and trusting community relationships; if the promoters develop a proactive and honest engagement strategy; if trusted experts are involved in the project; if the potential benefits are seen as outweighing the potential risks; and if the storage project is located in an area of low population density with a positive relationship with the fossil fuel industry. Simplifying, three issues can be said to be of particular relevance in terms of local reactions to CO_2 storage projects: trust in the developer, the quality of public engagement activities and public and stakeholder perceptions of the need for the facility. (Oltra, Upham et al. 2012)

There is evidence that CCS facilities are less likely to be accepted in rural areas and are seen as incompatible with tourism (von Rothkirch and Ejderyan 2021). Currently, carbon capture facilities in England are likely to be built in areas with existing similar industries. Familiarity with these industries and expectations about job creation and economic benefits may translate into lower risk perceptions of the technologies, leading to local acceptance (Oltra, Upham et al. 2012, Whitmarsh, Xenias et al. 2019). This will depend on

whether they have positive or negative perceptions of existing industry and the impacts it has had (L'Orange Seigo, Dohle et al. 2014). But, for many areas that have hosted fossil fuel infrastructure, CCS can represent a smoother transition which makes use of existing expertise and experience (von Rothkirch and Ejderyan 2021), including governance of the technology (Gough, Cunningham et al. 2018).

Experience with CCS in other countries has shown that it tends to be more accepted in areas of industrial decline which have experienced job losses and depopulation (von Rothkirch and Ejderyan 2021). While this can be advantageous to many stakeholders, a just transition would ensure that the shift to lower carbon industry does not take advantage of existing vulnerabilities and improves rather than exacerbates inequalities in the area (Swennenhuis, Mabon et al. 2020). Similarly, ethnic minority communities have been critical of some projects in the USA as they 'perceived discrimination in the selection process, as they were already burdened with the existing industrial developments and associated environmental problems' (von Rothkirch and Ejderyan 2021).

One study compared perceptions of CCS amongst the public and local stakeholders in Teesside and Lancashire. The participants in Lancashire drew on their experience with the siting of shale gas exploration in the area and sought reassurance about potential risks associated with storage including leakage. In Teesside, at a time of significant job losses, CCS was viewed very positively. It was seen as bringing economic opportunities and maintaining the area's industrial sector and technical expertise and 'as a "win-win" technology in terms of contributing to both the climate change agenda and the local economy' (Gough, Cunningham et al. 2018). However, this is not necessarily straightforward, as some stakeholders were also concerned that oil and gas workers may find low-carbon jobs less appealing if they have lower salaries than in the oil and gas industry and that trade unions may be unsupportive if they perceive that the transition will lead to job losses (Swennenhuis, Mabon et al. 2020).

The public dialogue research previously mentioned recruited research participants from Liverpool, Port Talbot, Aberdeen and Nottingham, which are all potential sites for CCUS except for Nottingham. It also found that residents expressed pride that Teesside would play a part in mitigating climate change, but one participant felt that, 'the region needed to move on from being the "dumping ground of every industry that's been going" and should focus instead on developing other sectors, such as digital companies' (Wickett-Whyte, Boelman et al. 2021). That research found that participants in Teesside and Aberdeen were most supportive of CCUS because of a belief that it would benefit local employment, including helping to replace oil and gas jobs in Aberdeen. Port Talbot residents were concerned about the cost of CCUS given the economic pressures on the steel industry. Participants in Liverpool were sceptical about whether jobs associated with CCUS would necessarily benefit local people. While participants in Teesside were more optimistic about CCUS and the sense of renewed pride it could give to the area, participants there were also worried about the realities of job creation. 'In all four locations, participants were cynical about patterns being repeated, where new jobs are announced only to disappear or be filled by workers from outside the area.' (Wickett-Whyte et al. 2021: 14)

Much of the earlier research on public perceptions of CCS focused on siting of projects and public responses to this. As this suggests, for members of the public, the first time they hear about a project is often once locations have been proposed and this is when public responses are activated. The content and tone of those responses will always be dependent on the context, and the extent to which residents feel they can input into decision-making, but this shows how critical this point in the process is. This has led researchers to propose that social scientists should characterise local contexts to anticipate community concerns, so these can be factored into decision-making about project location (von Rothkirch and Ejderyan 2021).

Beyond the specifics of locations and the communities who live there, the socio-political context can affect acceptance through a range of factors from trust in local government to controversies and crises in public trust, to shifts in public opinion and public discourses. As Oltra and colleagues explain:

> The broader socio-political context may influence how the public perceives the need for a proposed CO_2 storage project. National public debates may also influence local views. Political controversies in the community may also determine the local reaction to a facility or technology, as the project can be used for political battles. (Oltra, Upham et al. 2012)

There is some evidence that nationality can be a predictor of support for CCS (Witte 2021). Whitmarsh and colleagues (2019) found that survey respondents in the UK had the highest levels of support (both at the general and local levels), compared to respondents from the USA, Canada, Norway and the Netherlands. Broecks and colleagues (2021) compared opinions on CCS for participants in the UK and the Netherlands. They found that while the two countries share a similar national narrative about CCS implementation, the experience of negative public reaction to past onshore CCS projects in the Netherlands is reflected in lower public support than in the UK.

As these studies show, public perceptions and social acceptance of technologies and specific projects will always be a complex constellation of individual, community and broader socio-political factors that encompass elements as disparate as gender, concern about climate change, industrial history, cultural values and public confidence in governance mechanisms.

In the next section, four international case studies will be outlined, which illustrate many of the points outlined in this literature review.

6. Case Studies

6.1 Case Study 1: Tomakomai, Japan

Summary:

- Japan's first full-chain CCS demonstrator plant.
- Did not provoke public opposition and had widespread neutral or mildly supportive responses from residents.
- Public acceptance has been attributed to early and widespread public engagement, including site tours, support from local government and the fact that extensive environmental and seismic monitoring data was made publicly available.
- Local familiarity with the oil and gas industry and the fact this was a demonstrator likely added to public acceptance.

6.1.1 Project Characteristics

- Tomakomai used an amine process licenced from BASF, capturing CO_2 from gas generated from hydrogen production at an oil refinery.
- CO_2 was transported by pipelines to 1000m below the seabed in the subsurface of the Tomakomai port area.
- It was operational from 2016 until 2019, when it had achieved its aim of capturing 0.3 $MtCO_2$.
- It was commissioned by the Ministry of Economy, Trade and Industry (METI) and led by Japan CCS Co. Ltd. (JCCS)
- This was the first full-chain CCS demonstrator in a country prone to earthquakes and the first to reflect the London Protocol[3] (Tanaka et al. 2017).
- It was unusual being sited in a city with a population over 100,000 (and located close to the City Hall).
- The project was characterised by extensive monitoring and data collection, from baseline environmental data and monitoring of storage conditions to surveys of residents' opinions. Micro-seismicity and earthquakes were monitored throughout the project. (Tanaka, Sawada et al. 2017, IEA 2021, Japan CCS Co. Ltd. 2024)

6.1.2 Context

Tomakomai, which is in the northern prefecture of Hokkaido, has hosted heavy industry since the 1960s. This was initially met with public concerns about potential pollution, but energy infrastructure operators have come to be seen as '"good and trusted" employers in the city with a long record of conducting operations safely' (Mabon, Kita et al. 2017). Locals are aware of climate change and observed changes in weather patterns and

[3] https://www.imo.org/en/ourwork/environment/pages/london-convention-protocol.aspx

marine wildlife and indicated familiarity with citizen education initiatives in interviews with researchers (Mabon, Kita et al. 2017).

Fishing is an important local industry, and the fishing cooperatives are influential. Researchers (Mabon, Kita et al. 2017) found that fishers understood the need for CCS as a form of climate change mitigation, which they linked with potential effects on fish stocks and ocean acidification. They also have experience of marine pollution, so were somewhat cautious about storage below the seabed. However, the early environmental monitoring helped build trust between scientists and fishers and with the port authority, local government and others (Mabon, Kita et al. 2020).

Japan has a history of natural earthquakes and the area surrounding Tomakomai experienced two large earthquakes during the period of operation. While an expert panel concluded that there was no relation between the CCS operations and the earthquakes or evidence of leakage, it received attention on social media (Mabon, Kita et al. 2017).

Mabon et al. (2017) found that residents appear to trust local government, which has supported the CCS demonstrator: ‘the fact that municipal government officials live and work within the community, and hence themselves bear any potential risks from developments, may mean they come to be seen as reliable and trustworthy sources of information for citizens and stakeholders to reach their own informed decision on a proposed development’.

Similarly, Japan CCS Ltd. has acknowledged the significance of continuous data collection and the transparent sharing of results for securing public acceptance: ‘Monitoring is conducted as to whether the carbon dioxide will leak to the surface or into the sea, and if so, what the impact would be. Though it is almost inconceivable that it would leak into the living environment as the appropriate facilities (sites) have been selected in the first place, monitoring is necessary to enhance the safety of the project and to respond to public concerns’. (Japan CCS Co. Ltd. 2025)

6.1.3 Governance and Regulation

Japan has a 2050 net zero carbon emissions target, and CCS is at the heart of the government’s Green Transformation (GX) Strategy (Warren, Nguyen et al. 2025). There are 9 new sites due to be operational by 2030, with a mixture of domestic and overseas storage. The aim is to store 120-240 million tonnes of CO_2 per year by 2050 (Japan CCS Co. Ltd. 2024, Warren, Nguyen et al. 2025).

The CCS Business Act 2024 established a legal framework for CCU businesses, including setting out a licencing regime, property rights, safety and environmental standards and CO_2 transport regulation. The Advanced CCS Projects Initiative provides financial support for domestic and international projects.

Geological storage in Japan is regulated by the Act on Prevention of Marine Pollution and Maritime Disaster, which was enacted and amended to reflect the London Protocol. It requires marine environmental assessments to be conducted before a storage permit can be issued (Tanaka, Sawada et al. 2017).

During the construction phase, marine biologists conducted baseline surveys of the marine environment including observation of physical, chemical and biological aspects of seawater and sediment; this supported the environmental impact assessment which was required for the permitting process for injection and storage (Mabon, Kita et al. 2020).The injection system was monitored to ensure it was working effectively and to detect changes in pressure, temperature or vibrations. Storage conditions and any signs of leakage were also monitored.

6.1.4 Public Engagement

In the preparatory stages of the project, JCCS conducted a survey of residents, which identified a desire for information disclosure, consideration of safety and communication of risks and dissemination of information to young people amongst respondents. They have consequently conducted extensive social outreach activities since 2011. This includes panel exhibitions, lectures, classes and a cartoon explaining CCS for children, PR activities through the project website and social media and presentations at universities and industrial associations in Japan and internationally (Tanaka, Sawada et al. 2017). Tomakomai CCS Promotion Association was chaired by the city's mayor, with a range of stakeholders including local industry and fishing cooperatives. It set up a public information centre in the city centre and held annual open forums for residents which attracted 300-400 attendees and numerous site tours (Gładysz and Kupiec 2025).

6.1.5 Social Acceptance

Acceptance by local government, industry and the community has been seen as 'a must' for this project (Tanaka, Sawada et al. 2017). Some reservations about CCS have been expressed at the national level by NGOs including Friends of the Earth Japan and the Institute for Energy Economics and Financial Analysis, due to a concern that it will divert resources away from renewable energy, high costs and scepticism that it will be as effective as hoped (Coca 2024).

No strong opposition to the project has emerged locally. Initial caution and scepticism have dissipated over time, so when injection began in 2016, most residents viewed the project as both safe and as an investment in the city's future (Gładysz and Kupiec 2025).

Mabon and colleagues (2017) argue that 'building an understanding of the social, cultural and historical relationship between the community, industry and the sea is crucial to understanding the neutral or cautiously supportive response of the citizens and stakeholders in Tomakomai to the project'.

6.1.6 Lessons

The clear lesson from this case is the importance of early and ongoing, extensive and inclusive public engagement, which is led at the local level and includes many different stakeholders. In this case, public engagement was informed by knowledge about the context and the local community by having local government involvement and a survey of residents' views at the beginning of the process.

As well as providing residents and others with a range of information and the opportunity to visit the site, the constant monitoring and the fact that the data was publicly available would have reassured locals and given a sense that the project was being implemented in a transparent way. The fact that the developers acknowledged the seismicity of the area and openly monitored whether the demonstrator was affecting this would have strengthened perceptions of transparency. The fact that the demonstrator was sited close to the City Hall may have provided even greater reassurance about the safety of the project.

Tomakomai CCS demonstrator was sited in a city, and a country, which is exploring renewable energy but still has an active fossil fuel sector. Locals were familiar with heavy industry, so CCS did not appear as wholly new, but more an extension of existing industry. This would likely have reassured people, including those who work in the oil refinery, about the industry continuing in some form (and therefore avoiding the economic effects of the refinery being suddenly decommissioned) and, for those who are concerned about climate change, it may have provided reassurance that the city and the country is transitioning towards a lower-carbon future. An important lesson from this is that local acceptance is specific to the context, so it should not be assumed that other cities or regions of Japan would accept hosting a CCS facility in quite the same way.

6.2 Case Study 2: Sleipner, Norway

Summary:

- The world's first commercial CCS project, in operation since 1996. Viewed by many as proving the feasibility of permanent CO_2 storage.
- Has not experienced public opposition.
- Norwegians have higher levels of acceptance of carbon capture technologies than some other Europeans.

6.2.1 Project Characteristics

- Developed by Norway's state-owned energy company, Equinor (formerly, Statoil).[4]
- CO_2 is captured using an amine process from gas extracted in the Sleipner field.
- CO_2 is injected 800-1000m below the seabed in a deep saline aquifer in the Utsira formation in the North Sea, between Stavanger and Aberdeen.
- Around 1 $MtCO_2$ is sequestered per year. (MIT Carbon Capture and Sequestration Technologies Program n.d.)

6.2.2 Context

Oil and gas are Norway's most important export commodities and the basis for the nation's sovereign wealth fund, the largest in the world, which is managed to ensure wealth for current and future generations (Norges Bank Investment Management n.d.). Nonetheless, the Norwegian government has ambitious climate targets and introduced a carbon tax in 1991 to reduce emissions from its offshore oil and gas activities. The gas produced at Sleipner also has a high CO_2 content, at 9%, exceeding market requirements. CCS was a solution to both issues, as releasing the separated CO_2 to the air would have cost NOK 1 million per day in carbon taxes (Skalmeraas 2017, Dickson 2024, MIT Carbon Capture and Sequestration Technologies Program n.d.).

As the first commercial CCS operation, Sleipner has been an important source of data for subsequent CCS projects. It has been described as a 'benchmark' and as proof of the feasibility of long-term carbon storage (Skalmeraas 2017, Ma, Li et al. 2022). Many of the learnings have informed industry best practice and the EU Directive on geological storage of carbon dioxide (Skalmeraas 2017). Norway has also implemented further CCS projects including, most recently, developing Longship, the first cross-border CO_2 transport and storage infrastructure network.

The Institute for Energy Economics and Financial Analysis (IEEFA) has sounded a note of caution about celebrating Sleipner's successes without acknowledging some of the challenges it has faced in its thirty years of operation. For example, despite extensive surveys of the Utsira formation prior to injection, three years into operation, it was

[4] Equinor is also involved in UK CCS projects in Teesside.

discovered that there was a previously unidentified ninth layer in the formation and that CO_2 had risen to this layer, at the top extent of the storage formation (Hauber 2023). No CO_2 leakage has been detected, but the IEEFA argues that this example shows that, even with multiple studies, the security and stability of storage fields is not entirely predictable, which could present challenges for planning and regulation as new projects are rolled out internationally, especially for governments with fewer resources and less experience than Norway (Hauber 2023, Lefstad and Rivadeneira 2025).

6.2.3 Governance and Regulation

Norway incorporated the EU Directive on geological storage of carbon dioxide into national law through the Storage Regulation. It also has a Pollution Regulation which provides the legal framework for environmentally safe geological storage of CO_2, a Petroleum Regulation which sets out the conditions operators must fulfil to obtain exploration and operating licences and the CO_2 Safety Regulation, which protects safe working environments in exploration and exploitation of subsea CO_2 storage and transportation to these storage sites (Lefstad and Rivadeneira 2025). The Ministry of Petroleum and Energy has responsibility for granting licences under the Petroleum Regulation and the Storage Regulation. The Ministry of Environment and Climate oversees compliance with the Pollution Regulation and is responsible for granting storage permits, which requires an environmental impact assessment to estimate leakage risk.

6.2.4 Public Engagement

Sleipner is probably the most studied CCS project in the world, but the IEEFA points out that while extensive information is available, most is in the form of technical papers and not readily accessible to the public. There are reports that public engagement has been an important element in establishing CCS in Norway (Anon n.d.), though most examples refer to more recent projects than Sleipner. Jewad et al write:

> The Norwegian Government has proactively communicated the benefits of CCS, emphasising its role in reducing greenhouse gas emissions while maintaining industrial productivity. The success of Sleipner and Snøhvit [another CCS facility in Norway] has demonstrated the feasibility and safety of CCS, helping to build public trust. Further, Norway's active participation in international CCS initiatives and its efforts to develop cost-effective, scalable technologies has bolstered public support. By involving communities, addressing concerns transparently, and showcasing the environmental and economic advantages of CCS, Norway has fostered a positive public perception, positioning CCS as a key component of its climate strategy. (Jewad, Fattouh et al. 2024)

No citations or examples are included to substantiate these claims, so it is difficult to know what kinds of approaches the Norwegian government has used or to assess how this apparent success was achieved, but other articles draw similar conclusions (Tjernshaugen 2011, Patonia 2022).

6.2.5 Social Acceptance

The Norwegian public is generally both more aware and more supportive of CCS compared to people in other European countries, though they are less accepting of the idea of storing CO_2 that was captured in other countries. Their support is also conditional on CCS having a positive environmental impact (especially in relation to leakage), which may reflect the fact that Norwegians who are concerned about climate change are more likely to be supportive of CCS (Andersen, Nordø et al. 2022). As well as members of the public, several Norwegian NGOs are supportive of CCS (Jewad, Fattouh et al. 2024). Norway also has high levels of public trust in government (Sovacool, Fritz et al. 2025, Kellner, Feiring et al. 2026).

Norway's oil and gas sector is seen as foundational to the country's ongoing prosperity and geological storage of CO_2 is operated by Equinor, the state-owned oil and gas company, even though domestic power production largely comes from hydropower and Norwegians have been early and enthusiastic adopters of low-carbon technologies like electric cars and heat pumps. Given this context, it is perhaps not surprising that Norwegians are supportive of CCS: 'Since CCS currently seems to be the only set of technologies that give a significant chance for fossil fuels to remain relevant in a decarbonized world of tomorrow, this option is generally perceived by the Norwegian public as a necessary step to safeguard the welfare of its current and future generations' (Andersen, Nordø et al. 2022, Patonia 2022).

Another element that could have contributed to public acceptance of projects like Sleipner is the undersea storage location far from human settlements (Patonia 2022), though other studies have shown that offshore storage is not a guarantee of acceptance as many people worry about potential effects of leakage on marine environments (Mabon, Shackley et al. 2014).

6.2.6 Lessons

Sleipner is typically described as the project which established CCS as a viable technology. If carbon had leaked or other problems had emerged, it seems likely that the development of CCS could have suffered serious setbacks. While the carbon capture process had been achieved in projects in North America in the 1960s and 1970s through enhanced oil recovery, Sleipner shifted the focus to the storage aspect and the feasibility of permanent sequestration, thereby strengthening the argument for CCS as a form of climate change mitigation.

The long-term nature of carbon sequestration underlines the importance of ongoing environmental monitoring, contingency planning and having adequate resources to respond to issues that may emerge. This is not only a technical requirement, but also related to public acceptance, since support for this technology is conditional on it being effective at safely and permanently removing carbon from the atmosphere.

As with Tomakomai, CCS has been accepted in Norway because of the importance of the oil and gas industry. While the UK is much less reliant on fossil fuels both for economic growth and energy production, communities in areas that have hosted oil and gas production are often reassured by the fact that CCS can act as a bridge from high- to low-

carbon industries and thereby minimise the negative economic and societal impacts of the transition.

6.3 Case Study 3: Carbfix, Iceland

Summary:

- Developed a method of mineralising CO_2 for permanent geological storage.
- Carbfix's mineralisation and storage work has been accepted by the public. This has been attributed to extensive public engagement and positive media coverage. Mineralisation may have helped to allay public fears about leakage, and the continued involvement of academic researchers and funders and sharing of monitoring data have likely helped maintain public trust.
- Carbfix argue that the positive perceptions of their CO_2 storage work had a positive effect on the power plant where it has been developed, which had suffered a crisis in public trust after the economic crisis and some instances of unexpected induced seismicity.
- Plans to store imported CO_2 at the Coda Terminals have proven controversial, reflecting a sense that locals were not consulted, which was amplified by social media and reluctance about storing CO_2 from other countries.

6.3.1 Project Characteristics

- CO_2 is dissolved in water and injected into reactive rock formations like basalt, where it mineralises to form a solid carbonate mineral to be stored underground permanently.
- Mineralisation has a wide range of potential applications, and Carbfix are currently exploring the possibility of using seawater for injection.
- Carbfix began as an academic research project in 2006 and formalised as a company the following year. The company is developing 'point source' projects which capture CO_2 from a range of sources from geothermal energy to hard-to-abate industry, BECCS and direct air capture (with Swiss company Climeworks).
- Carbfix claims to have injected over 100,000 tonnes of CO_2 since 2014 and projects that the annual storage capacity for the existing pilot is 12,000 tonnes of CO2 (Carbfix n.d.).
- Carbfix is heavily involved in research and development and has received EU funding towards developing Coda Terminals, to mineralise and store carbon transported by ship from other countries.

6.3.2 Context

Following the Kyoto protocol coming into force in 2005, the then Icelandic president approached Reykjavík Energy and researchers from Iceland, France and the USA to design a project to reduce Iceland's greenhouse gas emissions (Gíslason, Sigurdardóttir et al. 2018). Storing carbon is a challenge in Iceland due to its geology but the team had expertise in basaltic rock, which is characteristic of Iceland. They designed a project to demonstrate the feasibility of storing carbon in basalt (Pind Aradóttir and Hjálmarsson 2018). It received 4 million Euros from Reykjavík Energy and 8 million Euros from EU and USA research funding programmes (Gíslason, Sigurdardóttir et al. 2018). This public-private partnership helped the company navigate the 2008 economic crisis.

There were initial technical setbacks in the pilot project, including the destruction of two distillation columns due to corrosion by hydrogen sulfide, which led to a refocusing of the project from carbon capture to storage. Despite the challenges, monitoring data indicated that more than 95% of the injected CO_2 mineralised within a year, demonstrating the potential for carbon to be permanently sequestered in basaltic bedrock (Gíslason, Sigurdardóttir et al. 2018).

6.3.3 Governance and Regulation

The Carbfix pilot needed to comply with national regulations covering issues including health and safety, environmental risks, planning and greenhouse gas emissions to secure several permits prior to CO_2 injection between 2007 and 2009 (Gíslason, Sigurdardóttir et al. 2018).

6.3.4 Public Engagement

Public engagement has been comprehensive since the early days of Carbfix, with information shared in scientific publications and in a range of media aimed at wider audiences including NGOs and the public. Carbfix have made numerous presentations, visited schools and held open days. They have also produced books on climate change and the carbon cycle in Icelandic and English, a guide for children, written non-technical articles nationally and internationally and participated in interviews on television and radio. Annual reports are published on the project website. According to Gislason et al, ‘All of this helped achieve the public acceptance of the Carbfix project, as well as a strong support of Reykjavík Energy’s managers’ (Gíslason, Sigurdardóttir et al. 2018).

Unexpected induced seismicity in 2011 generated a public and media response and concern amongst regulators and politicians. Reykjavík Energy held a town meeting to discuss the reinjection operation shortly after the biggest events and appointed a panel of independent experts to evaluate the operations. The panel recommended increased monitoring and making data available to scientists and establishing formal communications with the local population to alert them about risks of seismic activity. Communications were increased to improve transparency about seismic risks for the public, alongside regular reporting to regulators, permitting agencies and health inspection authorities (Thorsteinsson and Gunnarsson 2014, Pind Aradóttir and Hjálmarsson 2018).

6.3.5 Social Acceptance

It was understood from inception that public and government acceptance of the project was vital, and this was seen as one of the primary tasks of Carbfix’s manager (Gíslason, Sigurdardóttir et al. 2018). This was especially important since the Carbfix pilot project was located at the Hellisheiði geothermal power plant, which had faced financial challenges following the economic crisis and unexpected induced seismicity, both of which had diminished public trust in the plant and its operator, Reykjavík Energy. Yet rather than this lack of trust tainting public perceptions of Carbfix through association, Pind Aradóttir - who has been CEO of Carbfix since 2011 - and Hjálmarsson (2018) argue that Carbfix has enjoyed positive perceptions which have in turn improved Hellisheiði’s reputation. They

write that ‘The Carbfix team itself has not faced problems with public acceptance in relation to its carbon capture and storage (CCS) activities, as the public and authorities were engaged in the project from its inception’ (Pind Aradóttir and Hjálmarsson 2018). The project has received positive coverage from national and international media.

The more recent Carbfix project to establish Coda Terminals, which aims to mineralise 3Mt of imported CO_2, has proven more controversial (von Rothkirch, Guðlaugsson et al. 2025). As von Rothkirch and colleagues point out, this project might be assumed to be socially acceptable, as it addresses two established public concerns about CCS, in that the evidence shows that mineralisation happens relatively quickly and seems to be permanent, which could allay fears about CO_2 leakage, and because Carbfix intend to avoid storing carbon derived from the fossil fuel industry, thereby addressing criticisms of CCS that it diverts attention from the green energy transition.

The site chosen for the first Coda Terminal was initially enthusiastically accepted by local government. Carbfix carried out a range of public engagement activities and worked with community members to take their views into account, but once the proposed site of the boreholes became known, residents started to voice concerns on social media, which were picked up by the press.

Public concerns centred on uncertainties about scaling up, use of water resources, potential release of CO_2 into the sea or groundwater and induced seismicity. Other questions raised by stakeholders include whether the project represented Carbfix ‘experimenting’ on the local ecosystem, including disturbing its lava, which is protected by law; whether CCS was the right mitigation solution in this case; whether locals would benefit from the project; and whether Iceland bears responsibility for others’ emissions. The project received a very favourable environmental impact assessment from the planning authority and Carbfix launched their own social media campaign. Yet, these efforts did not increase support for the project and Carbfix has decided to instead investigate two potential alternative sites (von Rothkirch, Guðlaugsson et al. 2025).

6.3.6 Lessons

The controversy around the Coda Terminals demonstrates the importance of listening to locals’ concerns, even when they might seem outside of the scope of the discussions envisaged by developers. For example, residents at the initial storage site raised questions about the cost to local government of extending the harbour to accommodate the terminal. While this topic may have been beyond Carbfix’s remit, it is important to listen to such concerns, since they may be critical in securing public support for a project and therefore whether it is feasible. Being enabled to input meaningfully into early plans is beneficial to citizens and one of the reasons locals cited for stopping the project was a lack of consultation between the municipality and residents (von Rothkirch, Guðlaugsson et al. 2025).

Social media played an important role in mobilising opposition to the Coda Terminal site proposal. While there are inherent risks for messaging with social media, when people use it to express their concerns, this can indicate that they perceive a lack of forums in which they will be listened to. Von Rothkirch and colleagues write that Carbfix was perceived to have initially downplayed the risks of the project and had used overly positive or simplistic

language in explaining the Coda Terminals to the public, which undermined trust. Carbfix may have expected the public to accept this project because of their previous social acceptance, but public opinion can change over time and vary depending on specific projects and applications.

A key feature of this case is the perception that Iceland should not take responsibility for others' 'waste' products. Since several cross-border CO_2 projects are in development, this is likely to be an important emerging area of public perceptions to consider. In this case, von Rothkirch et al. (2025) report that Carbfix were perceived as adopting a defensive attitude that focused on the technicalities of the project and sometimes dismissed critics as climate sceptics rather than listening to people's concerns. They point out that this can alienate people and be perceived as avoiding difficult questions.

6.4 Case Study 4: Gorgon, Australia

Summary

- The world's biggest CCS facility.
- Has attracted criticism, especially from conservation and environmental groups and journalists, about its underperformance in terms of storage. While it is unclear what effect this has had on public perceptions, many expect it to negatively impact social acceptance.

6.4.1 Project Characteristics

- Full-chain CCS operation at a liquid natural gas plant with an estimated annual capture capacity of 1.6 MtCO_2 (IEA 2025), though Chevron claims it has capacity for up to 4 MtCO_2 (Chevron 2021).
- Uses activated methyl di-ethanol amine to remove CO_2, which is transported 7km and injected into a sandstone saline aquifer, the Dupuy Formation, more than 2000m underground (Marshall 2022).
- Led by Chevron with major partners including Shell and Exxon Mobil (IEA 2025). It received AUS$60m from the federal government's Low Emissions Technology Demonstration Fund (Cox 2021).
- Announced in 2009, commenced operations in 2019.

6.4.2 Context

Australia is one of the world's largest exporters of coal and gas (Marshall 2022). It also has the highest per capita greenhouse gas emissions in the OECD (IEA n.d.). The Australian government has been supportive of carbon capture both in terms of financial backing and enthusiastic framing.

In 2006, Western Australia's Environmental Protection Authority (EPA) responded to Chevron's proposal to develop Gorgon, concluding that the proposal could not be made environmentally acceptable and so should not be permitted to proceed (Environmental Protection Authority 2006). This was largely based on the likely impacts to some of the rare and endangered species on the island, but it also noted that the proposal to store CO_2 would have to be feasible, since, 'If injection did not occur, then the chief environmental benefit of locating this project on Barrow Island would be lost' (Environmental Protection Authority 2006). The then Minister for Environment nonetheless approved the proposal, subject to some conditions, in 2007 (State of Western Australia 2009).

In January 2021, reports emerged that the project had not been sequestering carbon at expected rates, due to sand infiltrating the injection system. The Western Australia Department of Mines, Industry Regulation and Safety capped the amount of carbon that could be injected to one third of its projected capacity while the problem was addressed (Milne 2021, Marshall 2022).

In 2024, Chevron reported that it had captured 10 MtCO_2 in its lifetime, a third of the amount initially predicted. This has led to renewed criticism of the plant and its operators,

and questions about whether its suboptimal performance undermines the case for CCS as a technology (Mercer 2024).

Barrow Island is a Class A nature reserve, and environmental NGOs have taken an interest in it from the beginning. NGOs and journalists have reported environmental issues on the island including methane leakage. One condition of Chevron's licence was to increase protection for the North West Shelf flatback turtles (State of Western Australia 2009), but an investigation is underway into erosion at beaches where these turtles nest and PFAS contamination (Milne 2025).

6.4.3 Governance and Regulation

In Australia, offshore storage within federal waters is permitted and regulated under federal legislation while onshore projects are primarily regulated by the relevant state or territory (Hoare, Allman et al. 2025). Most states use existing regulatory frameworks to enable onshore CCS, including the Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGSA) and the permitting regimes between states are broadly similar. Western Australia has specific legislation for CCS projects and released a CCUS Action Plan in 2024. Key elements include implementing a legislative and regulatory framework, engagement with industry to facilitate new projects, information-sharing, support for research and development and an Investment Attraction Fund aimed at expanding and diversifying jobs in the state (Hoare, Allman et al. 2025).

In 2020, a case was taken to Western Australia's Appeals Convener by environmental NGO the Conservation Council of Western Australia to challenge Chevron's operating licence. The appeal raised concerns about a lack of public disclosure about Gorgon's emissions, a lack of limits on its emissions and the length of its operating licence. The case was rejected on the first two grounds, but the operating licence was halved to ten years (Cox 2021).

The Australian government's Future Gas Strategy lays out plans to grow carbon storage. Regulatory reforms in 2023 imposed legal obligations on the largest emitters to reduce their emissions, funding is being targeted at research and development in hard-to-abate sectors and direct air capture, and legislation has been announced to facilitate cross-border storage (Hoare, Allman et al. 2025).

6.4.4 Public Engagement

Barrow Island is uninhabited by humans, so there was not a local community to engage. However, it should not be assumed that Australians will not be interested in Gorgon simply because they do not live nearby. No specific information about public engagement about the Gorgon project has been identified for this report, though a factsheet produced by Chevron was found (Chevron 2022).

The recent Western Australia CCUS Action Plan (Government of Western Australia 2024) observes, 'The Western Australian Government is committed to supporting early engagement and enduring partnerships between Government, industry, Aboriginal peoples and regional communities to ensure rights and interests are respected and the economic benefits are shared as the industry develops'.

As the largest CCS project in the world, Gorgon has been viewed as a bellwether for CCS in terms of performance, impacts and public perceptions and much commentary has characterised it as facing challenges in all these respects (Gładysz and Kupiec 2025). There has been minimal reporting from the operators and many of the problems outlined above have been identified through investigative journalism, despite the aim that Gorgon would demonstrate large-scale CCS feasibility (Marshall 2022).

6.4.5 Social Acceptance

Gorgon's licence from the Western Australia government is conditional on it storing 80% of the emissions from its LNG operation (Environmental Protection Authority 2006, Mercer 2024). Given its technical difficulties, many commentators and NGOs have raised questions about whether it will be possible to meet this condition and argued that this failure could undermine public confidence in CCS (Gorman and Searson 2021). A report by the Clean Air Task Force states:

> This example shows how important it is to engage early, communicate clearly, and manage expectations. Australia's experience underscores an important lesson: social acceptance can be undermined if a CCS project overpromises and underdelivers on performance. While communities may not follow injection volume statistics day-to-day, prominent failures or rule-bending will erode trust countrywide. ... In the public eye, Gorgon's struggles have been symbolic of the challenges facing CCS. The Gorgon case shows that earning a social licence is not a one-off task; it must be maintained through ensuring operational transparency, meeting commitments, and promptly addressing any issues (Gładysz and Kupiec 2025).

While several reports describe a lack of social licence for the Gorgon project, no clear evidence was found of specific objections from members of the public. Instead, the opposition seems to have been largely vocalised by journalists and NGOs. It is therefore difficult to say whether the Australian public support or oppose the Gorgon project, but there are indications that CCS provokes concerns about environmental impacts in Australia. For example, in 2024 the state of Queensland permanently banned CCS activities in the Great Artesian Basin area, which covers most of the state's landmass. This followed a proposed trial to inject 110,000 tonnes of CO_2 into an aquifer in the area, which was not approved by the Department of Environment, Science and Innovation due to the potential impacts on groundwater in the Great Artesian Basin, which over 180,000 people rely upon for water. The proposal was strongly opposed by a broad range of environmental and agricultural groups in the region (Chen 2024).

Gorgon's operators are only responsible for leakage from the plant during its lifetime and for fifteen years afterwards, with the federal and state government then assuming liability. If leakage does occur, this could prompt opposition from taxpayers about footing the bill for remediation as well as concerns about the emissions (Marshall 2022). As the think tank the Australia Institute has pointed out, even if it were running at full capacity, 4 MtCO_2 per year, Gorgon would only be capturing half of the plant's Scope 1 emissions (Ogge 2021). Both issues seem likely to provoke concerns amongst the public.

6.4.6 Lessons

As commentators have pointed out, if the world's largest CCS plant is storing carbon significantly below its projected capacity, this is bound to affect perceptions of the technology itself, not only amongst the public, but also potentially amongst government and regulators. Therefore, the challenges at Gorgon are likely to ripple out to other installations in Australia and elsewhere.

While sometimes it has been assumed that the public are disinterested in installations that happen far away, this project shows that out of sight is not necessarily out of mind. Some of the criticisms of Gorgon and the ban on CCS in Queensland suggest that there are significant concerns about the environmental impacts of CCS, for example on groundwater or wildlife, within Australia and that such concerns can affect public acceptance of CCS.

Gorgon also raises questions about who is responsible for dealing with, or reducing, carbon emissions and who pays for climate change mitigation and remediation of the environmental impacts of high-carbon industry. It seems likely that these could become future points of concern.

6.5 Overarching Lessons from the Case Studies

CO2 capture needs to be effective, and storage needs to be permanent

Given that one of the main public concerns about CCS is whether it is effective at sequestering CO_2, any uncertainty about insufficient capture or secure storage is likely to weaken public support.

Storage underperformance means not only lower confidence in the technology's effectiveness, but also that carbon is being emitted to the air rather than sequestered. This would be especially problematic for members of the public who are concerned about climate change. While controversies have focused on the storage aspect, over time the focus may shift towards the effectiveness of capture as well, since this also determines the extent to which CCS contributes to climate change mitigation.

Operations need to be safe and monitoring data shared transparently

The constant, ongoing and transparent monitoring of storage and seismicity at Tomakomai provided important scientific and technical data to inform operations but also informed and reassured the public. If the monitoring had shown negative effects or problems with storage, this would likely have weakened public acceptance of the project, as in the case of Gorgon. However, even when the results are disappointing, or monitoring is expanded after an incident as in the case of Carbfix, members of the public are likely to appreciate having been informed. If people believe that operators and regulators have been transparent, they will have greater confidence in their ability to address any problems that arise.

Information should be shared in a variety of formats and tailored to different audiences

The differences in communication style, media and messengers between the cases shows the importance of how information is shared with members of the public. Different individuals and communities find different sources of information and styles of dissemination more appealing, and this is reflected in the efforts made in Japan and Iceland to communicate with the public in a range of formats, including cartoons aimed at children, site tours and real-time data. Claims for the technology need to be realistic and setbacks should be reported transparently.

Pilots and demonstrators are crucial for building public trust

Beyond technical feasibility and commercial confidence, pilots and demonstrators inform regulators, government and the public and make the technology visible and familiar. Members of the public tend to trust projects that involve or are led by scientists over those which are run by private companies. Pilots and demonstrators are crucial because technical failures and public opposition can taint the reputation of the technology and any operators, funders or regulators associated with it.

The association between carbon capture and the oil and gas industry can have negative and positive effects on public acceptance

In most of the case studies discussed here, CCS was associated with oil and gas facilities rather than industrial decarbonisation, reflecting the fact that many of them have been operational for some time. This association can be reassuring to people and communities who are likely to be affected by declining oil and gas industries. But it can also mean that those who are more sceptical about carbon capture technologies will be suspicious that it is being used to avoid or delay other forms of emissions reduction.

Governance and local stakeholder relationships are critical to securing social acceptance

The case studies show the importance of local governments and regulatory agencies for securing public support. The support of local government seems to have had a positive effect on public acceptance in Tomakomai. But local government was perceived as overlooking local concerns in their enthusiasm for the Coda Terminals, which had a negative impact on social acceptance and ultimately led Carbfix to find a new site. This underlines the importance of understanding the context and the quality of relationships and levels of trust between different groups within communities where projects will be sited.

The perception of CO_2 as a waste product is a barrier to cross-border storage

Cross-border storage is being developed in all the countries in which the case studies are located; its potential is also being explored by UK-based projects. The controversy around Carbfix's Coda Terminals and other social science evidence suggests emerging public opposition to cross-border storage in the countries receiving CO_2. The opposition reflects a public perception of CO_2 as waste. If this gains traction, it could prove challenging for

developers of cross-border storage. If such facilities have technical issues with storage like Gorgon, this could also have serious implications for public perceptions.

CO_2 is also treated as waste from a regulatory perspective in the London Protocol, which prohibits dumping of waste at sea. While amendments to the protocol have been proposed to allow cross-border storage of CO_2 under the sea, these have not been formally adopted, though a resolution in 2019 allows for two or more countries to make an agreement for cross-border CO_2 storage (International Maritime Organization n.d.). If members of the public perceive CO_2 as a waste, this seems to provoke moral questions about who has responsibility for dealing with it, which could mean that operators and regulators will be held to a high level of accountability.

7. Conclusion

As the evidence discussed here has shown, public perceptions of CCS are tied to people's concerns about climate change in complex ways. Members of the public who are concerned about climate change want CCS to be deployed if it is effective at mitigating climate change, and if it does not crowd out other technologies and behavioural changes that will reduce and avoid carbon emissions. As carbon capture is expected to become increasingly applied to industrial decarbonisation rather than fossil fuel installations, public acceptance may increase.

Those who are less concerned about climate change appreciate the other benefits that CCS can bring like job creation, but ongoing support will be conditional on seeing those benefits realised. If people perceive that promises about the benefits of the technology (whether climate change mitigation, job creation or others) have been broken, they may also come to resent having to deal with CO_2, a substance that many perceive as waste and which most recognise as contributing to climate change.

The literature is clear on the need for early, ongoing, transparent and two-way public engagement around CCS. This is one way to build and maintain trust between different stakeholders. Compared to the early days of CCS, the public now has much greater access to information about these technologies, including through social media. Social media can be a forum for people to share non-evidence-based opinions, misinformation or disinformation, but it is also a place for people to go when they feel they are not being listened to. The controversies around some carbon capture projects that have been expressed on social media help underline the need for meaningful public engagement in which people's concerns can be heard and addressed.

As researchers build a greater body of evidence about the individual, community and broader socio-political factors that shape social acceptance, greater confidence can be placed in understanding public perceptions of CCS and anticipating how communities may respond to specific projects. Nonetheless, social acceptance or rejection cannot be assumed or taken for granted and it will always be crucial to include members of the public in conversations and decision-making about implementation and governance of this technology.

There are several areas where further social scientific research would be valuable as CCS and CCU projects are increasingly deployed in the coming years. Topics that may warrant further investigation by social scientists include:

- Comparative research which explores public perceptions of CCS alongside other carbon capture technologies including CCU, BECCS and DACCS, as well as research which focuses on carbon capture for industrial decarbonisation.
- Greater research on public trust in relation to CCS including perceptions of how the technology is regulated.
- As CCS becomes more familiar, research which investigates whether people are concerned about other emissions from the carbon capture process such as amine emissions, potential impacts on water resources and the impact of CO_2 pipelines.

- Real-world cases, to understand how the risks and benefits are distributed and what effect this has on public acceptance and the just transition.
- Research probing the perception of CO_2 as a ‘waste’ and assumptions about who has responsibility for dealing with it, especially in relation to cross-border CO_2 storage.

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